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Terahertz emission from InP

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Abstract

We investigate the generation of THz radiation by the application of ultra-short near-infrared optical pulses to bulk unbiased InP. The THz radiation is detected in the direction of the specular reflection. While the overall emission characteristics are similar to those displayed by InAs under similar excitation conditions, in contrast to InAs, a single-cycle only variation in THz signal, of about ±20%, is observed as the sample is rotated through 360° around the surface normal.

Keywords

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Terahertz emission from InP

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Abstract. We investigate the generation of THz radiation by the application of ultra-short near-infrared optical pulses to bulk unbiased InP. The THz radiation is detected in the direction of the specular reflection. While the overall emission characteristics are similar to those displayed by InAs under similar excitation conditions, in contrast to InAs, a single-cycle only variation in THz signal, of about $\pm 20\%$, is observed as the sample is rotated through 360° around the surface normal.

Keywords: THz, terahertz, InP
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INTRODUCTION

Semiconductors exhibit many diverse phenomena under terahertz-frequency electromagnetic radiation (THz) due to the energy of the THz photons corresponding to significant energy scales in bulk and low-dimensional materials and devices [1]. Semiconductors also serve as emitters of THz radiation when excited by ultra-short optical pulses, such as provided by femtosecond lasers. Surface field emitters, exemplified by InAs, emit in reflection, optimized at the Brewster angle [2]. The emission from photoconductors, such as GaAs, depends strongly on the incident pump power and the applied bias [3].

EXPERIMENT

Conventional time-domain spectroscopy was undertaken (Fig. 1) using a 12-fs Ti:sapphire laser of center frequency 790 nm and repetition rate 75 MHz. The emitter crystal surface normal was at 45° to the pump beam and the THz radiation detected in the specular reflection direction by birefringence in a ZnTe detector crystal.

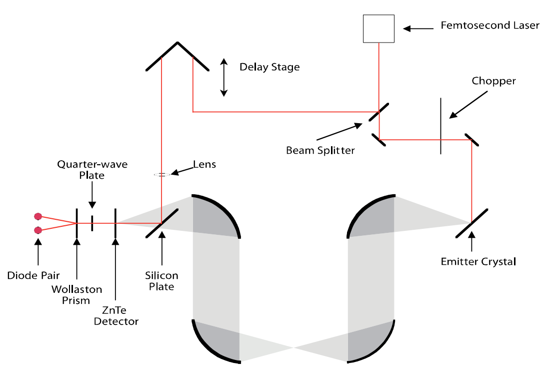

FIGURE 1. Main components of the experimental arrangement. The optical pump power was about 300 mW.

RESULTS AND DISCUSSION

Time-domain spectrum

Employing the delay stage to vary the arrival time of the probe beam relative to the THz pulse at the detector crystal (Fig. 1), a time-domain spectrum is obtained. The time-domain spectrum for InP is given in Fig. 2. In comparison with InAs, also shown, the THz electric field signal is approximately an order of magnitude less.

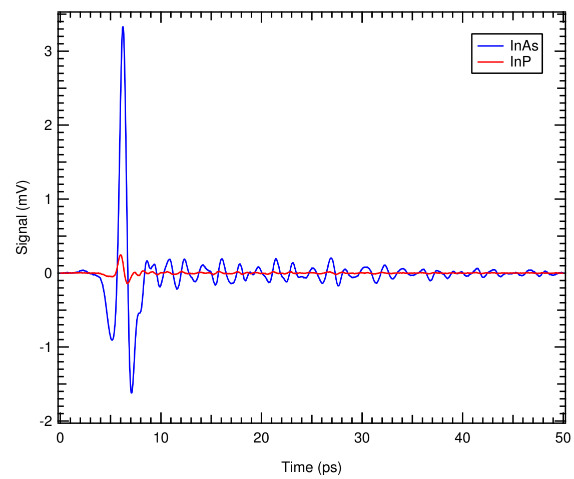

FIGURE 2. Time-domain spectra of THz emission from InP (red) and InAs (blue) under identical conditions of excitation.

Frequency-domain spectrum

The frequency-domain spectra for InP and InAs, as calculated from the data in Fig. 2, are given in Fig. 3. The vertical axes are uncalibrated but correct relative to each other. The ranges have been chosen so that the maxima

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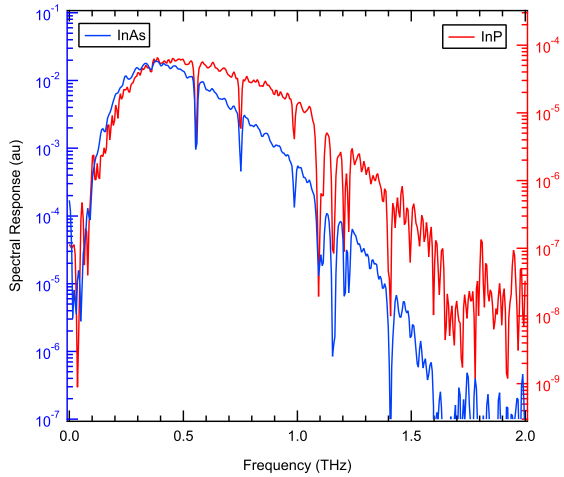

FIGURE 3. Frequency-domain spectra of InP (red) and InAs (blue) as calculated from the data of Fig. 2. The right axis applies to InP and the left axis to InAs.

correspond. It may be observed that, while the spectral density from InP is much less than that from InAs, the signal-to-noise ratios are similar, and that InP displays relatively more strength at higher frequencies.

Azimuthal angle dependence

The sample was rotated around the surface normal and the THz field strength measured as a function of the azimuthal angle. The data (dots) are given in Fig. 4 and fitted with a sine curve (full line).

The azimuthal angle dependence is used to distinguish the contribution from surface-field effects, which are expected to be independent of the angle, and optical rectification effects, which are strongly orientation dependent [4]. Our data gives evidence that both effects are involved. The larger contribution is from phenonmena that do not depend on the crystal orientation (surface-field effects). Imposed on this is a variation of $\pm 20\%$ which may be attributed to the optical rectification effect. Further studies are planned in which the optical pump power will be varied and a magnetic field applied in the plane of the crystal to fully explicate these mechanisms.

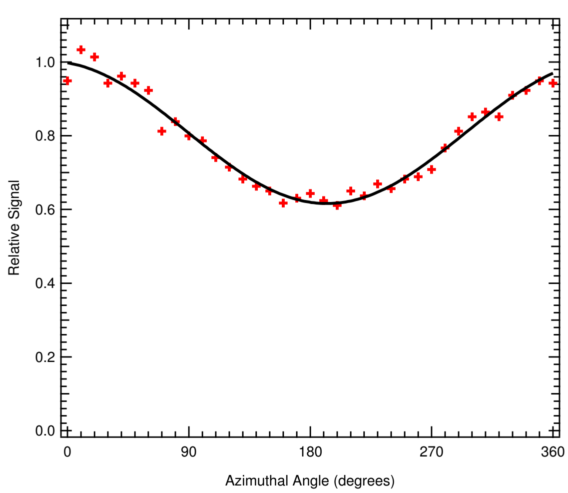

FIGURE 4. Dependence of THz electric field generated by InP on the azimuthal angle.

Previously when an azimuthal dependence is observed it usually displays a three-fold repetition through 360° rotation, associated with a <111> surface normal [5], or two-fold symmetry, associated with a <100> surface normal [6]. To our knowledge, this is the first report of a one-fold symmetry.

CONCLUSION

Coherent THz emission from InP has been observed and compared to that from InAs under identical conditions of excitation. Rotating the emitter crystal has indicated that the optical rectification effect plays a significant role, but that the main contribution is from surface-field effects. To put the THz emission from InP in context, when compared with other classes of emitters in our laboratory, under equivalent excitation conditions, InP is not as powerful as photoconductive antenna devices fabricated on GaAs, but is a stronger source of THz radiation than conventional optical rectification emitters such as ZnTe.

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